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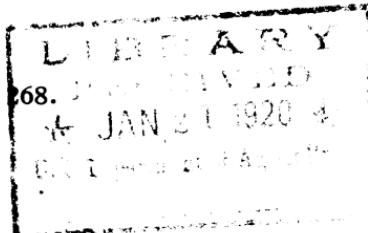
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Issued October 7, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN

[Revised, August 5, 1907.]



INDUSTRIAL ALCOHOL:

SOURCES AND MANUFACTURE.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., October 1, 1906.

SIR: It has been found impossible to reply by letter to the numerous inquiries coming to the Department regarding the manufacture of industrial (denatured) alcohol, its uses, and the regulations under which it may be used. A large number of the inquirers have the erroneous impression that the execution of the law is confided to the Department of Agriculture. In order to answer as fully as possible these inquiries and to inform the agricultural public as to the officials charged with the execution of the law, it is deemed advisable to issue two Farmers' Bulletins covering the subject. No. 268 is devoted to the description of the sources from which industrial alcohol may be made and the methods of manufacture; No. 269 gives some uses of industrial alcohol and statistics relating thereto. Certain text figures in the present bulletin are reproduced from drawings made from illustrations in several publications, namely: A brochure on The Giants' Causeway District, Maercker's Handbuch der Spiritusfabrikation, and Brannt's Distillation and Rectification, to which this acknowledgment is due.

Respectfully,

H. W. WILEY,
Chief, Bureau of Chemistry.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INDUSTRIAL ALCOHOL: SOURCES AND MANUFACTURE.

THE DENATURED ALCOHOL LAW.

On June 7, 1906, the following act of Congress (H. R. 17453, Public, No. 201) was approved, providing for the withdrawal from bond, tax free, of domestic alcohol when rendered unfit for use as a beverage or as a liquid medicine by mixture with suitable denaturing materials. The act reads in part as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after January first, nineteen hundred and seven, domestic alcohol of such degree of proof as may be prescribed by the Commissioner of Internal Revenue, and approved by the Secretary of the Treasury, may be withdrawn from bond without the payment of internal-revenue tax, for use in the arts and industries, and for fuel, light, and power, provided said alcohol shall have been mixed in the presence and under the direction of an authorized Government officer, after withdrawal from the distillery warehouse, with methyl alcohol or other denaturing material or materials, or admixture of the same, suitable to the use for which the alcohol is withdrawn but which destroys its character as a beverage and renders it unfit for liquid medicinal purposes; such denaturing to be done upon the application of any registered distillery in denaturing bonded warehouses specially designated or set apart for denaturing purposes only, and under conditions prescribed by the Commissioner of Internal Revenue with the approval of the Secretary of the Treasury.

The character and quantity of the said denaturing material and the conditions upon which said alcohol may be withdrawn free of tax shall be prescribed by the Commissioner of Internal Revenue, who shall, with the approval of the Secretary of the Treasury, make all necessary regulations for carrying into effect the provisions of this act.

Distillers, manufacturers, dealers, and all other persons furnishing, handling, or using alcohol withdrawn from bond under the provisions of this act shall keep such books and records, execute such bonds and render such returns as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may by regulation require.

Such books and records shall be open at all times to the inspection of any internal-revenue officer or agent.

SEC. 2. That any person who withdraws alcohol free of tax under the provisions of this act and regulations made in pursuance thereof, and who removes or conceals same, or is concerned in removing, depositing, or concealing same for the purpose of preventing the same from being denatured under governmental supervision, and any person who uses alcohol withdrawn from bond under the provisions of section one of this act for manufacturing any beverage or liquid medicinal preparation, or knowingly sells any beverage or liquid medicinal preparation made in whole or in part from such alcohol, or knowingly violates any of the provisions of this act, or who shall recover or attempt to recover by redistillation or by any other process or means, any alcohol rendered unfit for beverage or liquid medicinal purposes under the provisions of this act, or who knowingly uses, sells, conceals, or otherwise disposes of alcohol so recovered or redistilled, shall on conviction of each offense

be fined not more than five thousand dollars, or be imprisoned not more than five years, or both, and shall, in addition, forfeit to the United States all personal property used in connection with his business, together with the buildings and lots or parcels of ground constituting the premises on which said unlawful acts are performed or permitted to be performed: *Provided*, That manufacturers employing processes in which alcohol, used free of tax under the provisions of this act, is expressed or evaporated from the articles manufactured, shall be permitted to recover such alcohol and to have such alcohol restored to a condition suitable solely for reuse in manufacturing processes under such regulations as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, shall prescribe. * * *

The following amendment to the act of June 7, 1906, was approved on March 2, 1907:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That notwithstanding anything contained in the act entitled "An act for the withdrawal from bond tax free of domestic alcohol when rendered unfit for beverage or liquid medicinal uses by mixture with suitable denaturing materials," approved June seventh, nineteen hundred and six, domestic alcohol when suitably denatured may be withdrawn from bond without the payment of internal-revenue tax and used in the manufacture of ether and chloroform and other definite chemical substances where said alcohol is changed into some other chemical substance and does not appear in the finished product as alcohol: *Provided*, That rum of not less than one hundred and fifty degrees proof may be withdrawn, for denaturation only, in accordance with the provisions of said act of June seventh, nineteen hundred and six, and in accordance with the provisions of this Act.

SEC. 2. That the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may authorize the establishment of central denaturing bonded warehouses, other than those at distilleries, to which alcohol of the required proof may be transferred from distilleries or distillery bonded warehouses without the payment of internal-revenue tax, and in which such alcohol may be stored and denatured. The establishment, operation, and custody of such warehouses shall be under such regulations and upon the execution of such bonds as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may prescribe.

SEC. 3. That alcohol of the required proof may be drawn off, for denaturation only, from receiving cisterns in the cistern room of any distillery for transfer by pipes direct to any denaturing bonded warehouse on the distillery premises or to closed metal storage tanks situated in the distillery bonded warehouse, or from such storage tanks to any denaturing bonded warehouse on the distillery premises, and denatured alcohol may also be transported from the denaturing bonded warehouse, in such manner and by means of such packages, tanks or tank cars, and on the execution of such bonds, and under such regulations as the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury, may prescribe. And further, alcohol to be denatured may be withdrawn without the payment of internal-revenue tax from the distillery bonded warehouse for shipment to central denaturing plants in such packages, tanks and tank cars, under such regulations, and on the execution of such bonds as may be prescribed by the Commissioner of Internal Revenue, with the approval of the Secretary of the Treasury.

SEC. 4. That at distilleries producing alcohol from any substance whatever, for denaturation only, and having a daily spirit-producing capacity of not exceeding one hundred proof gallons, the use of cisterns or tanks of such size and construction as may be deemed expedient may be permitted in lieu of distillery bonded warehouses, and the production, storage, the manner and process of denaturing on the distillery premises the alcohol produced, and transportation of such alcohol, and the operation of such distilleries shall be upon the execution of such bonds and under such regulations as the Commissioner of

Internal Revenue, with the approval of the Secretary of the Treasury, may prescribe, and such distilleries may by such regulations be exempted from such provisions of the existing laws relating to distilleries as may be deemed expedient by said officials.

SEC. 5. That the provisions of this act shall take effect on September first, nineteen hundred and seven.

This amendment in effect creates a class of industrial distilleries in which industrial alcohol only may be produced, the daily output being limited to 100 proof gallons. The revised regulations of the Internal Revenue, Treasury Department, issued July 15, 1907, are very liberal in the interpretation of the law, and by relieving this class of distilleries of many restrictions placed upon larger establishments the production of industrial alcohol on a small scale is made practicable, provided that alcohol can be economically produced in small quantities under the conditions obtaining in any given locality.

There are no restrictions as to the materials to be used, the size of the still, nor its capacity, except that it shall not produce exceeding 100 proof gallons daily. The still must be registered, plans of the premises submitted, a bond given, and the distillery surveyed by a Government official. After this is done the distiller may control his operations almost entirely, notifying the collector of his district when he wishes to begin working. There is no reason why the small producer can not comply with these regulations, and furthermore the procedure for denaturing has been made very simple. The product can be denatured on the premises in any quantity or it can be sent to a central denaturing bonded warehouse and sold for denaturing purposes. If denatured on the premises it must be done under the supervision of the storekeeper gauger of that district, or if shipped to the central warehouse it must be drawn into packages and stamped by the same official.

The chief difficulty is that the alcohol produced must be 180 proof, which will require a certain form of still and some special knowledge to operate it. A wooden or pot still will not answer the purpose; a column still, preferably of the continuous type, being necessary. (See figs. 9 and 10.) The still must also comply in other particulars with the requirements of the Internal Revenue Regulations. Furthermore, only alcohol for denaturing purposes can be produced at these small industrial distilleries, that is, the production of potable alcohol can not take place under these conditions, which will prevent the farmer from distilling his high-grade materials to produce tax-paid spirits and using his low-grade material for the production of low-grade spirits for industrial purposes.

It is especially to be desired that the farmers of the country be not imbued with mistaken ideas respecting the character of this act and the relations which it bears to our agricultural interests. It is evident that so far as agriculture is concerned, the chief interest in

the act is in respect of the materials which are to be used in the manufacture of industrial alcohol, although under the act as amended the production of industrial alcohol on a small scale by the farmer may in some cases prove practicable.

INDUSTRIAL OR DENATURED ALCOHOL DEFINED.

The term "industrial alcohol" is used for brevity, and also because it differentiates sharply between alcohol used for beverages or for medicine and alcohol used for technical purposes in the arts.

The process of rendering alcohol unsuitable for drinking is called "denaturing," and consists, essentially, in adding to the alcohol a substance soluble therein of a bad taste or odor, or both, of an intensity which would render it impossible or impracticable to use the mixture as a drink.

The substance should also be of such a character that it is difficult to remove it entirely from the alcohol by any usual process of distillation.

Industrial alcohol, therefore, is a product which is the joint work of the farmer and the manufacturer. The function of the farmer consists in the production of the raw materials from which the alcohol is to be made. The manufacturer takes these raw materials and converts them into alcohol. This is done under the supervision and control of the Bureau of Internal Revenue of the Treasury Department. Thus, in point of fact, three different agents of activity are interested in the production of industrial alcohol—the farmer, the distiller, and the internal-revenue official.

The object of this bulletin is to make plain, in language as non-technical as possible, the principal points which are of interest in connection with this new industry of the production of industrial alcohol.

SUBSTANCES USED FOR DENATURING ALCOHOL.

The number of substances which have been mixed with alcohol to denature it is extremely large, and that particular denaturing agent should be selected which is best adapted to the special use to which the denatured alcohol is to be put. Among the substances which have been proposed are the following:

Gum shellac (with or without the addition of camphor, turpentine, wood spirit, etc.), colophonium, copal resin, Manila gum, camphor, turpentine, acetic acid, acetic ether, ethylic ether, methyl alcohol (wood alcohol), pyridin, acetone, methyl acetate, methyl violet, methylene blue, anilin blue, eosin, fluorescein, naphthalene, castor oil, benzin, carbolic acid, caustic soda, musk, animal oils, etc.

The materials and the quantities which are employed depend upon the purposes for which the denatured alcohol is to be used. There are many technical uses of alcohol, however, in which the

pure alcohol only can be employed, and it is a question to be decided by the Bureau of Internal Revenue whether such use of pure alcohol can be permitted under the existing law. The materials which are to be used for denaturing, the quantities thereof to be employed, and the warehouse in which denaturing can take place are fully described in the rules and regulations established by the Commissioner of Internal Revenue for carrying into effect the provisions of the law.^a

Methyl alcohol, benzin, and pyridin are the denaturing agents authorized by the Commissioner of Internal Revenue, in the following proportions: To 100 parts by volume of ethyl alcohol (not less than 90 per cent strength) add 10 parts of approved methyl (wood) alcohol and one-half of 1 part of approved benzin; or add 2 parts of approved methyl alcohol and one-half of 1 part of approved pyridin bases. Such alcohol is classed as completely denatured. Formulas for special denaturation may be submitted for approval by manufacturers to the Commissioner of Internal Revenue, who will determine whether they may be used or not, and only one special denaturant will be authorized for the same class of industries unless it shall be shown that there is good reason for additional special denaturants.

SOURCES OF POTABLE ALCOHOL.

The raw materials from which alcohol is made consist of those crops grown upon the farm which contain sugar, starch, gum, and cellulose (woody fiber) capable of being easily converted into a fermentable sugar. Alcohol as such is not used as a beverage. The alcohol occurring in distilled beverages is principally derived from Indian corn, rye, barley, and molasses. Alcohol is also produced for drinking purposes from fermented fruit juices, such as the juice of grapes, apples, peaches, etc. In the production of alcoholic beverages a careful selection of the materials is required in order that the desired character of drink may be secured. For instance, in the production of rum, the molasses derived from the manufacture of sugar from sugar cane is the principal raw material. In the fermentation of molasses a particular product is formed which by distillation gives the alcohol compound possessing the aroma and flavor of rum. In the making of brandy, only sound wine can be used as the raw material, and this sound wine, when subjected to distillation, gives a product containing the same kind of alcohol as is found in rum, but associated with the products of fermentation which give to the distillate a character entirely distinct and separate from that of rum. Again, when

^aRegulations No. 30, Revised U. S. Internal Revenue Regulations and Instructions Concerning Denatured Alcohol, under the act of Congress of June 7, 1906, and amending act of March 2, 1907. July 15, 1907.

barley malt or a mixture of barley malt and rye is properly mashed, fermented, and subjected to distillation, a product is obtained which, when properly concentrated and aged, becomes potable malt or rye whisky. In a similar manner, if Indian corn and barley malt are properly mashed, with a small portion of rye, the mash fermented and subjected to distillation, and the distillate properly prepared and aged, the product is known as bourbon whisky. Thus, every kind of alcoholic beverage gets its real character, taste, and aroma, not from the alcohol which it contains but from the products of fermentation which are obtained at the same time the alcohol is made and which are carried over with the alcohol at the time of distillation.

ALCOHOL DEFINED.

The term "alcohol" as used herein and as generally used means that particular product which is obtained by the fermentation of a sugar, or a starch converted into sugar, and which, from a chemical point of view, is a compound of the hypothetical substance "ethyl" with water, or with that part of water remaining after the separation of one of the atoms of hydrogen. This is a rather technical expression, but it is very difficult, without using technical language, to give a definition of alcohol from the chemical point of view. There are three elementary substances represented in alcohol: Carbon, the chemical symbol of which is C; hydrogen, symbol H; and oxygen, symbol O. These atoms are put together to form common alcohol, or, as it is called, ethyl alcohol, in which preparation 2 atoms of carbon and 5 atoms of hydrogen form the hypothetical substance "ethyl," and 1 atom of oxygen and 1 atom of hydrogen form the hydroxyl derived from water. The chemical symbol of alcohol therefore is C_2H_5OH . Absolutely pure ethyl alcohol is made only with great difficulty, and the purest commercial forms still have associated with them traces of other volatile products formed at the time of the distillation, chief among which is that group of alcohols to which the name "fusel oil" is applied. So far as industrial purposes are concerned, however, ethyl alcohol is the only component of any consequence, just as in regard to the character of beverages the ethyl alcohol is the component of least consequence.

AGRICULTURAL SOURCES OF INDUSTRIAL ALCOHOL.

The nature of alcohol having been briefly described, the next point to be considered is that of the greatest practical importance to the farmer, namely, the agricultural products from which the alcohol is to be made. It has already been pointed out that the chief alcohol-yielding material produced in farm crops is starch; the second impor-

tant material is sugar, and the third and least important raw material is cellulose, or woody fiber. The quantity of alcohol produced from cellulose is so small as to be of no importance at the present time, and therefore this source of alcohol will only be discussed under the heading "Utilization of waste material or by-products," "Wood pulp and sawdust" (see page 34).

STARCH-PRODUCING PLANTS.

Starch is a compound which, from the chemical point of view, belongs to the class known as carbohydrates, that is, compounds in which the element carbon is associated by a chemical union with water. Starch is therefore a compound made of carbon, hydrogen, and oxygen, existing in the proportion of 2 atoms of hydrogen to 1 atom of oxygen. Each molecule of starch contains at least 6 atoms of carbon, 10 atoms of hydrogen, and 5 atoms of oxygen. The simplest expression for starch is therefore $C_6H_{10}O_5$. Inasmuch as this is the simplest expression for what the chemist knows as a molecule of starch, and it is very probable that very many, perhaps a hundred or more, of these molecules exist together, the proper expression for starch from a chemical point of view would be $(C_6H_{10}O_5)_x$.

The principal starch-producing plants are the cereals, the potato, and cassava. With the potato may be classed, though not botanically related thereto, the sweet potato and the yam. Among cereals rice has the largest percentage of starch and oats the smallest. The potato, as grown for the table, has an average content of about 15 per cent of starch. When a potato is grown specifically for the production of alcohol it contains a larger quantity, or nearly 20 per cent. Cassava contains a larger percentage of starch than the potato, varying from 20 to 30 per cent.

SUGAR-PRODUCING PLANTS.

Sugar cane, etc.—While sugar is present in some degree in all vegetable growths, there are some plants which produce it in larger quantities than are required for immediate needs, and this sugar is stored in some part of the plant. Two plants are preeminently known for their richness in sugar, namely, the sugar cane and the sugar beet. In Louisiana the sugar canes contain from 9 to 14 per cent of sugar, and tropical canes contain a still larger amount.

The juices of the sugar beet contain from 12 to 18 per cent of sugar. There are other plants which produce large quantities of sugar, but which are less available for sugar-making purposes than those just mentioned. Among these, the sorghum must be first mentioned, containing in the stalk at the time the seed is just mature and the starch hardened from 9 to 15 per cent of sugar. Sorghum seed would also

yield as much alcohol as equal weights of Indian corn. The juices of the stalks of Indian corn contain at the time the grain is hardening and for some time thereafter large quantities of sugar, varying from 8 to 15 per cent.^a

According to analyses made during the season of 1906 at Washington the total sugars in the juices of Indian-corn stalks vary from 3 to 8 per cent. The quantity of sugar is materially increased by digesting with weak sulphuric acid, whereby a portion of the fiber and any starch or gum which may be present is converted into sugar.

Similar analyses have been conducted during this season at Hoopes-ton, Ill., in connection with a sweet-corn canning factory. In the juice of the stalks the quantity of the sugar found varies from 1 to 10 per cent. The cobs are also rich in sugar and starch. The sugar varies from 6 to 10 per cent and the starch from 8 to 13 per cent. The yield of alcohol varies from 6 to 10 per cent of the total weight of the cobs.

In the case of the sorghum and the Indian-corn stalk a large part of the sugar present is not cane sugar or sucrose, as it is commonly known, but the invert sugar derived therefrom. For the purposes of making alcohol the invert sugar is even more suitable than cane sugar. Many other plants contain notable quantities of sugar, but, with the exception of fruits, discussed under the following caption, not in sufficient quantities to be able to compete with those just mentioned for making either sugar or alcohol.

Fruits.—Nearly all fruit juices are rich in sugar, varying in content from 5 to 30 per cent. The sugar in fruits is composed of both cane sugar and its invert products (dextrose and levulose), in some fruits principally the latter. Of the common fruits the grape yields the largest percentage of sugar. The normal grape used for wine making contains from 16 to 30 per cent of sugar, the usual amount being about 20 per cent. Fruit juices are not usually employed in any country for making industrial alcohol, because of their very much greater value for the production of beverages. Inasmuch, however, as the orchards in this country often produce enormous quantities of fruits which can find no markets, the utilization of the common orchard fruits for making industrial alcohol would certainly be better than allowing them to go to waste. Moreover, the refuse which arises in the preparation of fruits for the market by evaporation, canning, or otherwise is rich in sugar and might be very properly used for making alcohol for industrial purposes (see also page 35).

Cane sugar, as has before been intimated, is not directly susceptible to fermentation. Chemically considered, it has the formula expressed

^a Annual Report of the Department of Agriculture, 1881-1882, p. 409.

by the following symbols: $C_{12}H_{22}O_{11}$. When cane sugar having the above composition becomes inverted, it is due to a process known as hydrolysis, which consists in the molecule of cane sugar taking up one molecule of water and splitting off into two molecules of sugar having the same formula but different physical and chemical properties. Thus the process may be represented as follows: $C_{12}H_{22}O_{11}$ (cane sugar) + H_2O (water) = $C_6H_{12}O_6$ (dextrose) + $C_6H_{12}O_6$ (levulose). These two sugars (dextrose and levulose) taken together are known as invert sugar and are directly susceptible to fermentation. All cane sugar assumes the form of invert sugar before it becomes fermented.

COMPOSITION AND YIELD OF ALCOHOL-PRODUCING CROPS.

In connection with the preceding description of the principal forms of raw material from which industrial alcohol can be made, more detailed information respecting the character and magnitude of the crops which may be utilized will be of interest.

Although alcohol could be made from other cereals produced in the United States besides those mentioned (i. e., it could be made from wheat, buckwheat, etc.), these crops are not and probably will not in the future be used for the manufacture of alcohol, and therefore no computations respecting the yields which could be produced therefrom are deemed necessary.

The weight of alcohol that may be produced from a given crop is estimated at a little less than one-half of the amount of fermentable substance present, it being understood that the fermentable substance is expressed in terms of sugar. Pasteur was the first to point out the fact that when sugar was fermented it yielded theoretically a little over one-half of its weight of alcohol. It must be remembered, however, that in the production of alcohol a process of hydrolysis is taking place which adds a certain quantity of alcohol to the products which are formed. For this reason a hundred parts of sugar yield more than a hundred parts of fermentable products. The distribution of the weights produced, as theoretically calculated by Pasteur, is as follows:

One hundred grams of sugar yield the following quantities of the products of fermentation:

	Grams. ^a
Alcohol.....	51.10
Carbonic acid.....	49.20
Glycerin.....	3.40
Organic acids, chiefly succinic.....	.65
Ethers, aldehydes, furfural, fat, etc.....	1.30
Total weight fermentation products produced.....	105.65

^a One gram equals 0.03527 ounce.

ARROWROOTS.

Various forms of starch-producing plants which are known as arrowroots yield large quantities of starch which is suitable for the manufacture of alcohol, but as these starches are very valuable for other purposes it is doubtful if this source of industrial alcohol will ever prove of any very great value. The arrowroots belong to the same general class as the cassavas. Sago is another source of starch which may prove to have some value for the manufacture of industrial spirits.

ARTICHOKEs.

The artichoke has been highly recommended and rather extensively used in Germany for the manufacture of alcohol. The fermentable material in the artichoke is neither starch nor sugar, but consists of a mixture of a number of carbohydrates of which inulin and levulin are the principal constituents. When these carbohydrate materials are hydrolyzed into sugars they produce levulose instead of dextrose. The levulose is equally as valuable as dextrose for the production of alcohol. Artichokes may be harvested either in the autumn or in the spring. As they keep well during the winter, and in a few places may be kept in hot weather, they form a raw material which can be stored for a long period and still be valuable for fermentation purposes. The mean composition of artichokes harvested in the spring and autumn is shown in the following table:

TABLE I.—*Composition of artichokes.^a*

Constituent.	Spring.	Fall.
	Per cent.	Per cent.
Water.....	79.03	79.70
Inulin.....	17.76	16.93
Fat.....	.18	.14
Protein.....	1.27	1.48
Ash.....	.99	1.08

^aBehrend, J. Landw., 1904, 59: 127.

Under the term "inulin" are included all the fermentable carbohydrates. The above data show, in round numbers, 17 per cent of fermentable matter. Theoretically, therefore, 100 pounds of artichokes would yield approximately 8½ pounds of industrial alcohol, or about a gallon and a quarter. The artichoke is not very extensively cultivated in this country, but it is probable that there are many localities where it might be grown to advantage. Its good keeping qualities recommend it as a material to keep the distilleries in operation when other more perishable materials are not available.

BANANAS.

The banana is a crop which grows in luxurious abundance in tropical countries, especially Guatemala and Nicaragua. The fruit contains large quantities of starch and sugar suitable for alcohol making. From 20 to 25 per cent of the weight of the banana consists of fermentable material. It is evident that in the countries where the banana grows in such luxuriance it would be a cheap source of industrial alcohol.

BARLEY.

A very important cereal in connection with the manufacture of alcohol is barley, which is quite universally employed for making malt, the malt in its turn being used for the conversion of the starch of other cereals into sugar in their preparation for fermentation.

Manufacture of malt.—Malt is made by the sprouting of barley at a low temperature (from 50° to 60° F.) until the small roots are formed and the germ has grown to the length of half an inch or more. The best malts are made at a low temperature requiring from 10 to 14 days for the growth of the barley. The barley is moistened and spread upon a floor, usually of cement, to the depth of a foot or 18 inches. As the barley becomes warm by the process of germination, it is turned from time to time and the room is kept well ventilated and cool. It is better at this point in the manufacture of malt to keep the temperature below 60° F. After the sprouting has been continued as above noted for the proper length of time, the barley is transferred to a dryer, where it is subjected to a low temperature at first and finally to a temperature not to exceed 140° or 158° F., until all the water is driven off, except 2 or 3 per cent. Great care must be exercised in drying the barley not to raise the temperature too high, lest the diastase which is formed be deprived of its active qualities. The malt has a sweetish taste, the principal portion of the starch having been converted into sugar, which is known chemically as "maltose." This sugar is, of course, utilized in the fermentation for the production of alcohol. Malt is chiefly valuable, however, not because of the amount of alcohol that may be produced therefrom, but from the fact that in quantities of about 10 per cent it is capable of converting the starch of the whole of the unmalted grains, whatever their origin may be, into maltose, thus preparing the starch for fermentation. Barley is not itself used in this country as a source of industrial alcohol, but it is employed for producing the highest grades of whisky, made of pure barley malt, which, after fermentation, is distilled in a pot still, concentrated in another pot still to the proper strength, placed in wood, and stored for a number of years. Barley malt is

too expensive a source of alcohol to justify its use for industrial purposes. It is, however, one of the cheapest and best methods of converting the starch of other cereals into sugar preparatory to fermentation.

Composition of barley.—A typical barley of the United States has the following composition:

Weight of 100 kernels.....	grams ..	4.533
Moisture.....	per cent ..	11.31
Proteids.....	do ..	10.61
Ether extract.....	do ..	2.09
Crude fiber.....	do ..	4.07
Ash.....	do ..	2.44
Carbohydrates, other than crude fiber.....	do ..	69.48

From the above analysis it is seen that barley has, in round numbers, about 68 per cent of fermentable matter. The weight of a bushel of barley (48 pounds) multiplied by 0.68 gives 32 pounds of fermentable matter in a bushel of barley.

Yield.—The acreage devoted to barley in the United States for the year ended December 31, 1905, is given as 5,095,528 acres; the yield per acre is 26.8 bushels, and the average farm price per bushel 40.3 cents. This refers to the unhulled barley. The total production of barley in the United States for the year mentioned is 136,651,020 bushels, valued at \$55,047,166. The State having the largest area in barley was California, with an acreage of 1,237,533, an average yield of 21.5 bushels, and a total production of 26,606,960 bushels, worth at the farm 59 cents per bushel and valued at \$15,698,106. Minnesota had the next largest area in barley, namely, 1,074,538 acres, yielding 27 bushels per acre, or a total yield of 29,012,526 bushels, worth 32 cents per bushel, or a total value of \$9,284,008.^a Other large barley producing States are North Dakota, Wisconsin, and South Dakota.

The crop reports of the United States show no barley at all from a number of the States, including a majority of the Southern States, Massachusetts, Rhode Island, Connecticut, New Jersey, and Delaware.

CASSAVA.

Composition.—Cassava is grown over a large area of the South Atlantic and Gulf States of this country. Numerous analyses have been made in the Bureau of Chemistry of the cassava root and of cassava flour, and from among these the following typical analyses have been selected.

^a Yearbook U. S. Dept. of Agriculture, 1905, Appendix.

TABLE II.—Composition of peeled cassava root and of the fiber and bark of the root.

Constituent.	Peeled root.		Fiber after removal of starch—dry.	Bark of root.	
	Fresh.	Dry.		Fresh.	Dry.
Moisture.....	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fat (ether extract).....	61.30	0.30	61.30
Protein (nitrogen \times 6.25).....	.17	0.4466	1.70
Starch (diastase extract inverted with hydrochloric acid).....	.64	1.66	1.02	2.29	5.91
Fiber.....	30.98	80.06	64.64	3.83	9.89
Ash.....	.88	2.26	10.68	2.02	5.23
Undetermined.....	.51	1.31	1.42	29.90	77.27
Total.....	5.52	14.27	21.94	100.00	100.00
	100.00	100.00	100.00	100.00	100.00

TABLE III.—Composition of cassava root (dry matter).

	Per cent.
Ash.....	1.94
Petroleum ether extract (fat).....	1.27
Ether extract (resins, organic acids, etc.).....	.74
Alcohol extract (amids, sugars, glucosids, etc.).....	17.43
Crude fiber.....	4.03
Starch.....	71.85
Protein (nitrogen \times 6.25).....	3.47

TABLE IV.—Composition of cassava flour.

Constituent.	Serial No. 5922.	Serial No. 5923.
	Per cent.	Per cent.
Moisture.....	10.56	11.86
Ash.....	1.86	1.13
Petroleum ether extract (fat).....	1.50	.86
Ether extract (resins and organic acids).....	.64	.43
Alcohol extract (amids, sugars, glucosids).....	13.69	4.50
Dextrin, gum, etc., by difference.....	2.85	5.63
Crude fiber.....	2.96	4.15
Protein (nitrogen \times 6.25).....	1.31	1.31
Starch.....	64.63	70.13

The above data show that of all the substances which have been mentioned, except the cereals, cassava contains the largest amount of alcoholic or fermentable substances. The root, deprived of its outer envelop, was found to contain a little over 30 per cent of starch, while the undetermined matter in the analyses is principally sugar. If this be added to the starch, it is seen that approximately 35 per cent of the fresh root is fermentable. This of course represents a very high grade of cassava, the ordinary roots containing very much less fermentable matter than the figures just given. If, however, it is assumed that the fermentable matter of cassava root will average 25 per cent, this amount is much greater than the average of the potato, or even of the sweet potato and the yam. Twenty-five per cent is undoubtedly a low average content of fermentable matter. In the dry root there was found nearly 72 per cent of starch and 17 per cent of extract, principally sugar. Assuming that 15 per cent of this was fermentable, and adding this to the 72 per cent, it is seen

that 87 per cent of the dry matter of the cassava is fermentable. This appears to be a very high figure, but it doubtless represents almost exactly the conditions which exist. It would be perfectly safe to say, discounting any exceptional qualities of the samples examined, that 80 per cent of the dry matter of the cassava root is capable of being converted into alcohol. It thus becomes in a dry state a source of alcohol almost as valuable, pound for pound, as rice.

Yield.—Very extravagant statements have been made respecting the yield of cassava roots which can be obtained per acre. Reports have been received in the Bureau of Chemistry showing a yield of 30 or 40 tons. Careful examinations, however, of actual conditions show that if 5 tons per acre of roots is obtained it is an average yield. In very many cases, where no fertilizer is used and where the roots are grown in the ordinary manner, the yield is far less than this, while with improved methods of agriculture it is greater. In the analysis of the peeled root, given above, the sample was taken from a large quantity of roots taken promiscuously from Florida sources. The composition given may be taken to represent the average ordinary market root at the period of its greatest value for alcohol making. The bark of the root, as is seen, has very little fermentable matter in it. If the whole root be considered, the percentage of starch is less than it would be for the peeled root. If cassava yields 4 tons, or 8,000 pounds, per acre and contains 25 per cent of fermentable matter the total weight of fermentable matter is 2,000 pounds, yielding approximately 1,000 pounds of 95 per cent alcohol, or 143 gallons of 95 per cent alcohol per acre. It is believed that when the principles of the culture of cassava are well established and the methods of manuring fully developed the yield will be very much greater than that figured above. In so far as the writer knows the cassava root has never been utilized for the manufacture of alcohol. By reason of the large quantity of sugar which the cassava contains, amounting to sometimes as much as 5 or 6 per cent, there is a large waste of fermentable matter if starch is made, since the sugar is all washed away. For the manufacture of industrial alcohol it is evident that the pulped root should be used for fermentation after the conversion of the starch into sugar in the ordinary manner.

CORN (INDIAN CORN OR MAIZE).^a

Yield.—The crop which at the present time is the source of almost all of the alcohol made in the United States is Indian corn. The estimated acreage of this crop in 1905 was 94,011,369 acres, and the yield 2,707,993,540 bushels.

^a See also use of stalks of Indian corn and sorghum, page 33.

The average price per bushel throughout the United States, based on the farm price on December 1, 1905, was 41.2 cents,^a and the total value of the crop at the farm, \$1,116,696,738. The largest acreage in Indian corn in any one State in the United States was in Illinois, namely, 9,616,886 acres; the average yield per acre is 39.8 bushels, and the total yield 382,752,063 bushels. At 38 cents per bushel the total value is \$145,445,784. From one State, Nevada, no report is made, showing a practical absence of Indian corn under cultivation. The smallest quantity produced in any State represented in the statistics is in Wyoming, the acreage under cultivation being 2,107, the yield per acre 26.9 bushels, and the total yield 56,678 bushels, with an average farm value of 75 cents per bushel, making the total value of the crop \$42,508. The average yield for all the States per acre was 28.8 bushels. The highest yield per acre was in Connecticut, namely, 42.7 bushels per acre, and the lowest in Florida, the average yield being 10.1 bushels per acre. It is thus seen that Indian corn is grown in appreciable quantities in every State of the Union, except Nevada. The acreage is the largest of all crops and the yield in bushels larger than that of any other crop. The highest farm price per bushel of Indian corn was found in Arizona, where the average price was 97 cents, and the lowest price per bushel in South Dakota, namely, 31 cents.

Composition.—As already stated, most of the alcohol made in the United States for beverages or for industrial purposes is made from Indian corn. The principal centers of manufacture for alcohol are Terre Haute, Ind., and Peoria, Ill. The typical composition of Indian corn as grown in the United States is shown in the following table:

Weight of 100 kernels	grams ..	38.979
Moisture	per cent ..	10.93
Protein	do ..	9.88
Ether extract (oil)	do ..	4.17
Crude fiber	do ..	1.71
Ash	do ..	1.36
Carbohydrates, ^b other than crude fiber	do ..	71.95

From these data it is seen that the fermentable matter in Indian corn—that is, the part which is capable of being converted into alcohol—amounts to nearly 70 per cent of the total weight, since the unfermentable cellulose and pentosans included in carbohydrates do not exceed 2 per cent. Inasmuch as a bushel of Indian corn weighs 56 pounds, the total weight of fermentable matter therein, in round

^a Yearbook U. S. Dept. of Agriculture, 1905, Appendix.

^b Starch, sugar, soluble cellulose, pentosans, etc. Pentosans are a form of woody fiber differing from cellulose in that when treated with acid they form an unfermentable sugar called xylose, from the Greek word for "wood."

numbers, is 39 pounds. The weight of the alcohol which is produced under the best conditions is little less than one-half of the fermentable matter. Therefore the total weight of alcohol which would be yielded by a bushel of average Indian corn would be, in round numbers, about 19 pounds. The weight of a gallon of 95 per cent alcohol is nearly 7 pounds. Hence 1 bushel of corn would produce 2.7 gallons.

If the average price of Indian corn be placed, in round numbers, at 40 cents a bushel, the cost of the raw material—that is, of the Indian corn—for manufacturing 95 per cent industrial alcohol is about 15 cents a gallon. To this must be added the cost of manufacture, storage, etc., which is perhaps as much more, making the estimated actual cost of industrial alcohol of 95 per cent strength made from Indian corn about 30 cents per gallon. If to this be added the profits of the manufacturer and dealer, it appears that under the conditions cited industrial alcohol, untaxed, should be sold for about 40 cents per gallon.

POTATOES.

The Potato Crop in the United States.

Yield.—Potatoes are produced in every State and Territory of the United States. The statistics for the year ended December 31, 1905, show that the total area devoted to potatoes in the United States is 2,996,757 acres. The largest area in any one State is found in New York, namely, 428,986 acres, and the smallest area, aside from Arizona, not reported, is found in New Mexico, namely, 1,470 acres. The yield of potatoes for the year is given as 260,741,294 bushels; the largest total yield was in New York, the average yield per acre for the country being 87 bushels. The largest yield per acre is reported from Maine, namely, 175 bushels, and the smallest from Louisiana and Texas, namely, 64 bushels per acre. The average price per bushel for the whole country at the farm is 61.7 cents, making the total value of the crop \$160,821,080. The highest price per bushel was obtained in Florida, namely, \$1.20, and the lowest price per bushel in Nebraska, namely, 37 cents. The weight of a bushel of potatoes is 60 pounds. As the average amount of fermentable matter in potatoes grown in the United States is 20 per cent, the total weight of fermentable matter in a bushel of potatoes is 12 pounds, which would yield approximately 6 pounds or 3.6 quarts of alcohol.

Composition.—*Starch content:* The quantity of starch in American grown potatoes varies from 15 to 20 per cent. Probably 18 per cent might be stated as the general average of the best grades of potatoes. In this connection it must be remembered that at the present time potatoes are grown in the United States chiefly for table use.

Generally, only the imperfect or injured samples are used for stock feeding or for starch making, and this condition will probably continue as long as good edible potatoes bring a higher price for table use than can be obtained by utilizing them for starch or for feeding purposes.

Under the microscope the granules of potato starch have a distinctive appearance. They appear as egg-shaped bodies on which, especially the larger ones, various ringlike lines are seen. With a modified light under certain conditions of observation a black cross



FIG. 1.—Potato starch ($\times 300$).

is developed upon the granule. It is not difficult for an expert microscopist to distinguish potato from other forms of starch by this appearance, which is well shown in figs. 1 and 2.

The quantity of protein in the potato is quite low compared with that of cereal foods; in round numbers it may be said to be 2.5 per cent. The potato contains very little material which is capable of fermentation aside from starch and sugars.

Sugar content: Although the potato is not sweet to the taste in a fresh state, it contains notable quantities of sugar. This sugar is lost whenever the potato is used for starch-making purposes, but is util-

ized when it is used for the manufacture of industrial alcohol. The percentage of sugar of all kinds in the potato rarely goes above 1 per cent. The average quantity is probably not far from 0.35 per cent, including sugar, reducing sugar, and dextrin, all of which are soluble in water. In the treatment of potatoes for starch making therefore it may be estimated that 0.35 per cent of fermentable matter is lost in the wash water.

One German author, Saare, claims to have found much larger quantities of sugar in potatoes than those just mentioned. The



FIG. 2.—Potato starch viewed with modified light ($\times 300$).

minimum quantity found by this author is 0.4 per cent, and the maximum 3.4 per cent, giving a mean of 1.9 per cent. Ten varieties of potatoes used for the manufacture of industrial alcohol were examined in the securing of these data. It appears that some varieties have a greater tendency to produce sugar than others. The German variety known as "Daber" contains the smallest quantities of sugar, while the variety known as "Juno" contains the largest quantities. The percentages of sugar, as reported by Saare, however, are larger than those reported by other observers, and probably are larger than are usually found.

Average composition: Frazier, of the Cornell station, has collected analyses of a large number of different varieties of potatoes and finds them to have the following average composition:

	Per cent.
Water.....	75.00
Starch.....	19.87
Sugars and dextrin.....	.77
Fat.....	.08
Cellulose.....	.33
Ash.....	1.00

The following analyses show in detail the composition of potatoes from different localities:

Analysis of Maine potatoes: The Bureau of Chemistry a few years ago made an investigation in connection with the experiment station in Maine of the composition of potatoes grown in that State used for table purposes and for starch making. Some of the best varieties grown in different parts of the State were subjected to analysis and the following results show them to be of quite uniform composition:

TABLE V.—Analyses of Maine potatoes.^a

Variety.	Water.	Starch.	Fiber.	Protein nitrogen $\times 6.25$.	Ash.	Specific gravity.
Hebron.....	79.72	16.94	.90	2.12	.76	1.0604
Do.....	78.13	18.59	.72	2.06	.78	1.0795
White Elephant.....	76.81	19.96	.84	2.19	.99	1.0867
Do.....	76.92	20.38	.90	2.31	.87	1.0742
Do.....	78.74	15.96	.64	2.25	.92	1.0803
Do.....	75.21	19.31	.61	2.12	.83	1.1058
Do.....	75.88	18.81	.56	2.25	.96	1.0921
Do.....	77.44	18.12	.63	2.06	.88	1.0906
Do.....	75.56	18.14	.56	1.81	1.04	1.1129
Do.....	78.13	18.62	.63	1.75	.98	1.0881
Delaware.....	76.02	19.20	.61	2.06	1.01	1.0852
Do.....	76.93	18.63	.61	2.19	.94	1.0904
Do.....	75.72	18.63	.55	2.31	.95	1.0745
Carmen.....	77.64	16.26	.61	2.56	.91	1.1120
Do.....	76.87	18.03	.66	2.06	.90	1.0967
Average.....	76.57	17.07	.59	2.38	.76	1.0804
	77.02	18.29	.66	2.16	.91	1.0881

^a Maine Agr. Exp. Sta., Bul. 57, p. 147.

Analysis of Vermont potatoes: Analyses made in Vermont and published in the report of the Vermont Experiment Station for 1901 show an average content of starch considerably less than that above given, namely:

	Per cent.
Water.....	79.41
Starch.....	14.51
Sugars and dextrins.....	1.44
Cellulose.....	.36
Protein.....	2.28
Ether extract.....	.06
Ash.....	1.26
Undetermined.....	.68

Composition of Potatoes used in France for Industrial Purposes.

The following is regarded in France as an average composition of the potato suitable for industrial purposes:^a

	Per cent.
Water.....	71.00
Starch.....	18.00
Sugar, etc.....	1.06
Cellulose.....	1.65
Protein.....	2.12
Fat.....	.11
Ash.....	1.60

The total fermentable matter, as seen above, is a little over 19 per cent, not allowing anything for the cellulose which is fermented. As a portion of the cellulose may also become a source of alcohol, it is observed that the average percentage of fermented matter in the French potato used for industrial purposes is not far from 20 per cent.

The following varieties show a variation in starch content of 6.8 per cent, the minimum being 15.9 and the maximum 22.7 per cent:

	Per cent of starch.
Red Starchy.....	22.7
Shaw.....	20.5
Institute of Beauvais.....	17.7
Kernours.....	17.9
White Elephant.....	16.0
British Red.....	16.0
Giant Blue.....	15.9

Analysis of Potatoes from German Sources.

Average composition and starch content.—The content of starch in potatoes examined in the laboratory of the Association of German Spirit Manufacturers during the year 1905 varied from 12.1 to 25.1 per cent. Eleven per cent of the total number examined contained between 12 and 14 per cent of starch, 20 per cent between 14 and 16 per cent of starch, 13 per cent between 16 and 18 per cent of starch, 24 per cent between 18 and 20 per cent, 24 per cent also between 20 and 22 per cent and 8 per cent between 22 and 25.1 per cent.

These data show that 56 per cent of the total number of samples examined contained between 18 and 25 per cent of starch. It is evident therefore that the general average content of starch in the potatoes used in the German distilleries is not far from 18 to 20 per cent.

^a Encyclopédie Agricole, E. Saillard.

The mean composition of potatoes is given by three German authorities, namely, König, Lintner, and Wolff, as follows:

TABLE VI.—*Average analysis of potatoes by three German authorities.*

Constituent.	König. Per cent.	Lintner. Per cent.	Wolff. Per cent.
Water.....	75.48	76.0	75.0
Protein.....	1.95	2.1	2.1
Fat.....	.15	.2	.2
Starch and sugar.....	20.69	19.7	20.7
Crude cellulose.....	.75	.8	1.1
Ash.....	.98	1.2	.9

The above data show the average content of fermentable matter in German potatoes, as determined by three of their leading authorities, to be about 20 per cent. The potatoes used for the manufacture of alcohol in Germany are not of the variety raised for edible purposes. In a large number of experiment stations in Germany systematic efforts have been made for many years to grow a potato rich in starch without respect to its edible qualities. These potatoes are coarser in structure and less palatable than those grown for the table. The object of the cultivation of this class of potatoes is to produce as much starch and other fermentable matters per acre as possible. It is evident that our own experiment stations should undertake work of a similar character if the potato is to be used to any great extent in the manufacture of industrial alcohol. There is no doubt of the fact that success equal to that attained by the German experimenters will attend any systematic efforts of this kind in our country. Not only will larger crops per acre of potatoes be grown, but these potatoes will contain larger quantities of starch and other fermentable substances. If the crop of potatoes is to remain at the present average, namely, less than 100 bushels per acre, profitable returns for alcohol making can not be expected, either by the farmer or by the manufacturer. A much larger quantity must be grown and, if possible, at less expense, in order that encouraging profits may be realized.

Maercker, one of the most celebrated of German authors, states that in certain instances the potato in Germany reaches a very high starch content. Some varieties, in exceptional instances, have shown as high as 29.4 per cent, 28.1 per cent, and 27.3 per cent, respectively. In warm, dry seasons potatoes often are found containing from 25 to 27 per cent of starch. According to Maercker, the sugar content, including all forms of sugar, varies greatly. Perfectly ripe potatoes contain generally no sugar or only a fractional per cent. When potatoes are stored under unfavorable conditions, large quantities of sugar may be developed, amounting to as high as

5 per cent altogether. In general, it may be stated that the content of sugar of all kinds will vary from 0.4 per cent to 3.4 per cent, according to conditions.

Ash analyses.—The mineral matters which the potato extracts from the soil or from the fertilizers which are added thereto consist chiefly of phosphate of potash. The mean average composition of the ash of the potato is shown in the following table:^a

	Per cent.
Potash (K_2O).....	60.37
Soda (Na_2O).....	2.62
Lime (CaO).....	2.57
Magnesia (MgO).....	4.69
Iron oxid (Fe_2O_3).....	1.18
Phosphoric acid (P_2O_5).....	17.33
Sulphuric acid (SO_3).....	6.49
Silicic acid (SiO_2).....	2.13
Chlorin.....	3.11

This analysis was made upon the so-called pure ash, deprived of its unburned carbon, and freed of sand and carbon dioxid.

Effect of fertilization on the yield and starch content.—Experience in Germany has shown not only that liberal fertilization with nitrogen is favorable to the production of a large crop of potatoes, but also that this is accomplished without decreasing the percentage of starch therein. The following table shows the increase in yield, percentage of starch, and amount of starch obtained by nitrogen fertilization, the results being expressed in hectares^b and kilograms:^c

TABLE VII.—*Effect of nitrogen fertilization on yield and starch content of potatoes.*^d

Variety of potato.	Without nitrogen.			With nitrogen.		
	Starch.	Yield of tubers per hectare.	Yield of starch per hectare.	Starch.	Yield of tubers per hectare.	Yield of starch per hectare.
	Per cent.	Kilograms.	Kilograms.	Per cent.	Kilograms.	Kilograms.
Seed.....	18.01	20,900	3,780	18.17	24,870	4,507
Champion.....	21.33	19,510	4,152	21.48	24,470	5,233
Imperator.....	19.00	22,560	4,235	18.70	26,830	5,007
Magnum Bonum.....	18.41	19,170	3,522	18.07	22,510	4,057
Aurelie.....	19.47	18,950	3,653	19.75	23,550	4,609
Reichskanzler.....	22.78	14,300	3,236	22.61	17,250	3,875
Juno.....	19.33	17,590	3,422	19.92	20,900	4,199
Amaranth.....	22.47	16,180	3,619	22.84	18,310	4,188
Charlotte.....	19.42	17,041	3,305	19.67	20,774	4,081
Gelbfleischige Zwiebel.....	19.97	19,888	3,946	19.91	21,772	4,323
Dabersche.....	21.82	17,377	3,778	21.80	20,313	4,399
Weissfleischige Zwiebel.....	20.51	16,877	3,442	20.58	19,501	3,936
Schneeroese.....	18.84	19,653	3,724	18.66	22,343	4,186
Nassengrunder.....	19.08	19,701	3,725	22.12	21,889	4,813
Gebe Rose.....	21.09	16,847	3,547	20.60	20,177	4,129
Hortensie.....	17.72	22,416	3,907	17.45	26,381	4,532
Richters Lange Weisse.....	19.37	22,134	4,267	19.19	24,490	4,664
Rosalie.....	18.27	19,866	3,557	18.25	22,186	4,003
Achilles.....	21.02	18,886	3,962	20.93	20,913	4,376
Alcohol.....	16.47	16,270	2,673	16.31	20,339	3,327
Average.....	19.77	18,806	3,673	19.85	21,998	4,322

^a Maercker, Handbuch der Spiritusfabrikation, p. 99.

^b 1 hectare=2.471 acres.

^c 1 kilogram=2.205 pounds.

^d Maercker, Handbuch der Spiritusfabrikation, 1890, 5th ed., p. 48.

It is evident from the data given in the table that the liberal application of nitrogenous fertilizers increases the yield per acre of tubers and of starch to a very marked extent, although the average percentage of starch present is increased very little. Converting the average data given in Table VII into their equivalents in pounds per acre, we have the following results: Without nitrogen—yield of tubers, 16,781 pounds per acre; yield of starch, 3,277 pounds per acre. With nitrogen—yield of tubers, 19,629 pounds per acre; yield of starch, 3,856 pounds per acre.

The following varieties of potatoes are considered in Germany the best for the manufacture of alcohol: Wohltman, Silesia, Agricultural Union, Athenena, Prince Bismarck, Richter's Imperator, and Maercker. The latest consular report^a on the potato as a source of alcohol in Germany shows the following yields per acre and percentages of starch:

TABLE VIII.—*Yield and starch content of potatoes grown in Germany for alcohol production.*

Varieties.	Yield per acre.	Starch.
	Bushels.	Per cent.
Professor Wohltman.....	342.0	16.3
Idung.....	284.5	16.4
Topaz.....	326.0	17.3
Sas.....	399.0	18.3
Leo.....	412.0	17.0
Richter's Imperator.....	476.0	15.4
Silesia.....	367.5	16.3
Professor Maercker.....	428.0	14.5

Comparative Values of Potatoes and Other Root Crops for Making Alcohol.

Of all the common root crops, the potatoes, including the yam and the sweet potato, are the most valuable for the production of alcohol, meaning by this term that they contain more fermentable matter for 100 pounds than other root crops. This is shown by the following comparative statement:

	Per cent.
White turnips.....	6 to 8
Rutabagas.....	8 to 13
Mangel-wurzels.....	8 to 15
Carrots.....	8 to 16
Parsnips.....	8 to 17
Sugar beets.....	10 to 22
Potatoes, sweet potatoes, and yams.....	14 to 26

In the above are given in approximately correct quantities in round numbers the percentages of fermentable matter contained in ordinary root crops. While it is seen that sugar beets, carrots, and parsnips contain relatively large amounts of fermentable matter, these roots could not compete with potatoes even if they could all be produced at the same price per 100 pounds.

^a No. 2654, August 30, 1906.

Price at which Potatoes can be Profitably Used for Alcohol Making.

A general review of all the data indicates that under the most favorable circumstances and with potatoes which have been bred especially for the purpose an average content of fermentable matter of about 20 per cent may be reasonably expected. It is thus seen that approximately 10 pounds of industrial alcohol can be made from 100 pounds of potatoes. If 60 pounds be taken as the average weight of a bushel of potatoes, there are found therein 12 pounds of fermentable matter, from which 6 pounds of industrial alcohol can be produced, or six-sevenths of a gallon. It has also been shown that at the prices quoted in 1905 the amount of Indian corn necessary for the production of a gallon of industrial alcohol costs not less than 15 cents. From this it is evident that the potatoes for alcohol making will have to be produced at a cost of not to exceed 15 cents per bushel, before they can compete with Indian corn for the manufacture of industrial alcohol.

RICE.

Composition.—Rice is not used to any great extent in this country for making alcohol, but it is extensively used for this purpose in Japan and some other countries, and has the largest percentage of fermentable matter of all the cereals. If it be considered in the hulled form, its typical composition is as follows:

Weight of 100 kernels.....	grams ..	2.20
Moisture.....	per cent ..	12.40
Proteids.....	do ..	7.50
Ether extract	do ..	.40
Crude fiber.....	do ..	.40
Ash.....	do ..	.50
Carbohydrates, other than crude fiber.....	do ..	78.80

It is seen that the percentage of fermentable matter in rice is nearly 78 per cent. A bushel of rice weighs, unhulled, 45 pounds, hulled, 56 pounds, and it therefore has about 34 and 43 pounds, respectively, of fermentable matter for the unhulled and the hulled rice. It is not probable that rice will ever be used to any extent in this country as a source of industrial alcohol, although it is used to a large extent in the manufacture of beverages, as for instance in beers, which are often made partly of rice.

Yield.—The area devoted to rice in the United States for the year 1905 was 482,479 acres, yielding 28.2 bushels per acre, or a total of 13,606,989 bushels, valued at the farm at 95.2 cents a bushel, or a total value of \$12,955,748. The largest rice-producing area is in Louisiana, in which there were 240,037 acres devoted to rice, yielding 25.8 bushels per acre, or a total production of 6,192,955 bushels, valued at 89 cents a bushel, or \$5,511,730. Texas, with a smaller

acreage, namely, 214,490 acres, produces a yield of 31 bushels per acre, amounting to 6,649,190 bushels, worth \$1 per bushel, having a total value of \$6,649,190, a greater value than that of the crop in Louisiana. The other Southern States which produce rice yield only small quantities, the largest yield, besides those mentioned, being in South Carolina, in which 18,114 acres were reported as devoted to rice culture

RYE.

Composition.—Large quantities of alcohol, chiefly in the form of alcoholic beverages, are manufactured from rye. It is, in connection with Indian corn, the principal source of the whiskies made in the United States. Rye, however, is not used to any extent in this or other countries for making industrial alcohol. The composition of a typical sample of rye as grown in the United States is as follows:

Weight of 100 kernels.....	grams..	2.50
Moisture.....	per cent..	10.50
Proteids.....	do....	12.25
Ether extract.....	do....	1.50
Crude fiber.....	do....	2.10
Carbohydrates, other than crude fiber.....	do....	71.75
Ash.....	do....	1.90

Yield.—The total acreage devoted to rye in the United States for the year 1905 was 1,730,159. The average yield per acre is given as 16.5 bushels, and the total production 28,485,952 bushels, valued at the farm at 61.1 cents per bushel and having a total value of \$17,414,138. The largest rye-producing State is Pennsylvania, in which there were 346,265 acres devoted to this cereal, with an average yield of 17 bushels per acre, and a total yield of 5,886,505 bushels, valued at 65 cents a bushel, with a total value of \$3,826,228. Other large rye-producing States in the order mentioned are Wisconsin, Nebraska, New York, and Michigan. A number of the Southern States make no returns for rye whatever.

From the analysis given it is seen that rye contains almost as much fermentable matter as Indian corn. A bushel of rye weighs 56 pounds. Wheat and other cereals, not mentioned above, are not used in this country to any appreciable extent in the manufacture of alcohol.

SPELT.

This grain, which is botanically a variety of wheat, more closely resembles barley, and, though not yet grown to any great extent in this country, there is a tendency, especially in the West, to increase its cultivation for stock feeding, due chiefly to its prolific growth. Under favorable conditions as high as 73 bushels per acre have been reported by the North Dakota station, and the analyses given show 70 per

cent of fermentable carbohydrates. The weight per bushel is about the same as that of oats. It would appear that this crop might be worthy of consideration as a profitable source of industrial alcohol.

SUGAR BEETS.

The sugar beet is often used directly as a source of alcohol. Working on a practical scale in France, it has been found that from 10,430 tons of beets there were produced 183,624 gallons of crude alcohol of 100° strength. The beets contain 11.33 per cent of sugar. From 220 pounds of sugar 15.64 gallons of alcohol were produced. The weight of pure alcohol obtained is a little less than one-half the weight of the dry fermentable matter calculated as sugar subjected to fermentation. About 18 gallons of alcohol are produced for each ton of sugar beets employed.

SWEET POTATOES.

Yield and composition.—The sweet potato has not been used in the United States for the making of alcohol. In the Azores great quantities of sweet potatoes are grown for this purpose, and make an alcohol of fine quality, which is used to a large extent in fortifying port wines. There are large areas in the United States, especially in the Southern States, where the sweet potato can be grown in great abundance. The experiments at the South Carolina station show that as high as 11,000 pounds of sweet potatoes can be grown per acre. The percentage of starch is markedly greater than in the white or Irish potato. In all cases over 20 per cent of starch was obtained in the South Carolina sweet potatoes, and in one instance over 24 per cent. As high as 2,600 pounds of starch were produced per acre.

In addition to starch, the sweet potato contains notable quantities of sugar, sometimes as high as 6 per cent being present, so that the total fermentable matter in the sweet potato may be reckoned at the minimum at 25 per cent. A bushel of sweet potatoes weighs 55 pounds, and one-quarter of this is fermentable matter, or nearly 14 pounds. This would yield, approximately, 7 pounds, or a little over 1 gallon of 95 per cent alcohol. It may be fairly stated, therefore, in a general way, that a bushel of sweet potatoes will yield 1 gallon of industrial alcohol. The average yield of sweet potatoes, of course, is very much less than that given in the South Carolina reports, where heavy fertilization was practiced. On plots to which no fertilizer was added the yield was about 8,000 pounds of sweet potatoes per acre, yielding in round numbers 1,900 pounds of starch. The quantity of sugar in the 8,000 pounds is about 350 pounds, which, added to the starch, makes 2,250 pounds of fermentable matter per

acre. This will yield 1,125 pounds of industrial alcohol of 95 per cent strength, or approximately 160 gallons per acre.

The yield of sweet potatoes in the above computation must be regarded as exceptionally high. A safer calculation will be based upon the yield of 100 bushels of sweet potatoes per acre, a little above the average of the yield of the potato, or a total of 5,500 pounds per acre. One-quarter of this amount is fermentable matter—about 1,400 pounds—which would yield, approximately, 700 pounds of 95 per cent alcohol, or 100 gallons of 95 per cent alcohol per acre. In addition to the sugar in the form of sucrose, or common sugar, which the sweet potato contains, there is also an appreciable amount of noncrystallizable sugars. The total sugars in the sweet potato have not been overstated in the above estimate. In fact, the contrary, rather, is true, since the two sugars together probably average about 6 per cent of the weight of the potato. If the average quantity of starch in the sweet potato is 20 per cent, which is rather a low estimate, the total fermentable matter in the sweet potato is 26 per cent instead of 25 per cent, as estimated above.

Effect of storage on composition.—Experiments have shown that the quantity of starch diminishes and the quantity of sugar increases on storing. Further, it may be stated that in the varieties of sweet potatoes which are most esteemed for table use there is less starch and perhaps more sugar than are stated in the above examples. In one instance of an analysis made on the 7th of January of stored potatoes, the starch had fallen to a little less than 13 per cent, while the sugars had increased to over 11 per cent. The total quantity of fermentable matter, however, as will be seen, had not been greatly changed, although there was probably a slight loss. In the southern agricultural work referred to the yam and the sweet potato are considered together. The composition and the changes on keeping are well illustrated by the following data:

TABLE IX.—*Changes in composition of the sweet potato of different varieties on storing.^a*
FIRST LOT (NOVEMBER 28).

Name of variety.	Original.				Air dry.				Water free.			
	Water.	Starch.	Glucose.	Sucrose.	Water.	Starch.	Glucose.	Sucrose.	Starch.	Glucose.	Sucrose.	
Georgia Buck.....	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
75.35	13.13	0.77	4.31	6.79	49.65	2.93	16.31	53.27	3.14	17.50		
Bunch Yam.....	72.37	15.12	1.09	4.45	6.67	51.06	3.67	15.04	54.71	3.93	16.11	
Do.....	67.99	19.58	.56	4.49	7.24	56.70	1.61	13.02	61.18	1.74	14.04	
Horton Yam.....	70.29	15.06	1.05	6.23	6.24	47.52	3.31	19.67	50.68	3.53	20.98	
Georgia Buck.....	71.56	14.35	.73	6.61	6.88	46.98	2.40	21.63	50.45	2.58	13.23	
Vineless Yam.....	70.03	16.85	.54	5.01	7.90	51.78	1.67	15.40	56.22	1.81	16.72	
Hanover Yam.....	76.16	13.61	1.10	4.22	7.37	52.89	4.29	16.40	57.10	4.63	17.70	
Georgia Yam.....	70.01	18.87	1.00	4.08	7.57	58.17	3.07	12.59	62.93	3.32	13.62	
Average.....	71.72	15.82	.86	4.93	7.08	51.84	2.87	16.26	55.82	3.09	16.16	

^a South Carolina Agr. Exp. Sta., Bul. 63, p. 25.

TABLE IX.—*Changes in composition of the sweet potato, etc.*—Continued.

SECOND LOT (JANUARY 7).

Name of variety.	Original.				Air dry.				Water free.		
	Water.	Starch.	Glucose.	Sucrose.	Water.	Starch.	Glucose.	Sucrose.	Starch.	Glucose.	Sucrose.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Georgia Buck.....	69.74	12.72	1.75	9.25	8.80	38.34	5.27	27.87	42.04	5.78	30.56
Bunch Yam.....	67.31	13.66	2.02	9.90	9.49	37.83	5.60	27.40	41.80	6.19	30.27
Do.....	67.29	13.83	2.40	9.43	10.00	38.04	6.61	25.94	42.27	7.34	28.82
Horton Yam.....	71.39	9.57	2.57	9.69	7.18	31.05	8.35	31.43	33.45	9.00	33.86
Georgia Buck.....	67.63	14.43	2.12	7.85	8.46	40.80	6.00	22.21	44.57	6.55	24.26
Vineless Yam.....	67.33	12.03	2.90	10.09	7.90	33.90	8.19	28.44	36.81	8.89	30.88
Hanover Yam.....	70.13	14.13	1.66	6.58	9.29	42.90	5.05	19.99	47.29	5.57	22.04
Georgia Yam.....	71.78	11.21	2.26	8.10	8.62	36.30	7.31	26.24	39.72	8.00	28.72
Average.....	69.08	12.70	2.21	8.86	8.72	37.40	6.55	26.19	40.99	7.17	28.68

The above data apparently are sufficient to show the high value which attaches to the sweet potato and the yam, not only as edibles, but especially for the purpose of making alcohol. It is also seen that the sweet potato would not be a valuable material for making starch alone, because in starch making the sugar which the sweet potato contains is lost, whereas in the manufacture of alcohol the sugar and the starch, as well as any fermentable celluloses or gums in the potato, are utilized. The following table shows the extent to which this crop is grown in the United States:

TABLE X.—*Acreage and production of sweet potatoes (including yams) in the United States by States, in 1899, as reported by the Twelfth Census.*

States.	Acres.	Bushels.	States.	Acres.	Bushels.
United States.....	537,447	42,526,696	Mississippi.....	38,169	2,817,386
Alabama.....	50,865	3,457,386	Missouri.....	9,844	743,377
Arizona.....	51	4,299	Nebraska.....	551	48,224
Arkansas.....	13,271	998,767	Nevada.....	5	923
California.....	1,007	239,029	New Hampshire.....	1	6
Colorado.....	20	2,291	New Jersey.....	20,588	2,418,641
Connecticut.....	2	130	New Mexico.....	47	6,180
Delaware.....	2,265	222,165	New York.....	73	8,681
District of Columbia.....	145	19,936	North Carolina.....	68,730	5,781,587
Florida.....	22,791	2,049,784	North Dakota.....	1	1
Georgia.....	70,620	5,087,674	Ohio.....	3,796	249,767
Hawaii.....	135	9,284	Oklahoma.....	2,512	195,799
Idaho.....	6	413	Oregon.....	27	2,825
Illinois.....	7,534	511,605	Pennsylvania.....	3,443	234,724
Indiana.....	3,989	239,487	Rhode Island.....	1	102
Indian Territory.....	1,064	80,364	South Carolina.....	48,831	3,369,957
Iowa.....	2,688	224,622	South Dakota.....	3	105
Kansas.....	4,570	474,810	Tennessee.....	23,374	1,571,575
Kentucky.....	14,178	925,786	Texas.....	43,561	3,299,135
Louisiana.....	27,372	1,865,482	Utah.....	40	4,958
Maryland.....	6,469	677,848	Vermont.....	4	306
Massachusetts.....		23	Virginia.....	40,681	4,470,602
Michigan.....	71	3,242	Washington.....	52	4,672
Minnesota.....	4	136	West Virginia.....	3,393	202,424
			Wisconsin.....	4	86

UTILIZATION OF WASTE MATERIAL OR BY-PRODUCTS.

STALKS OF INDIAN CORN AND SORGHUM.

The stalks of sweet corn, field corn, and sorghum contain large quantities of sugars, and also considerable amounts of starch at the time of the hardening of the starch in the seeds. When sweet corn is harvested for the market its stalk contains considerable quantities of fermentable matter, as has already been stated. Large quantities of this material are grown in the United States every year, and after the harvest of the sweet corn for the market the stalks are utilized chiefly for fodder. In the curing of the stalks for fodder the sugars ferment and disappear. If these stalks could be used economically they would add largely to the raw materials from which alcohol could be made. The technical difficulties, however, attending the utilization of the stalks are so great that it is doubtful whether means can be devised whereby their use may be made profitable for alcohol making. Notwithstanding this, it is a matter which is well worthy of investigation, because if stalks of sweet corn and field corn could be utilized they would place at the disposal of the manufacturer an almost inexhaustible source of raw material from which alcohol might be made. At the present time, however, there is no immediate probability of the economic utilization of this material.

The stalks of sorghum, as is well known, contain very large quantities of fermentable matter at the time of ripening. All of these bodies—that is, the stalks of sweet corn, field corn, and sorghum—contain, in addition to the sugar, notable quantities of starch and gum, which after conversion into a sugar, by malt or otherwise, add greatly to their value for alcohol making. In so far as the question of raw materials is concerned there are no other sources available in the United States so abundant as those found in sweet corn, field corn, and sorghum stalks.

The great difficulty encountered in connection with the utilization of these materials is that the season in which these stalks are suitable for utilization in the manufacture of alcohol is very limited. For instance, in the vicinity of Washington none of these stalks would be available until the latter part of July, and their availability would not continue later than the middle or the end of October under the most favorable circumstances. This gives at most a manufacturing period of only two or three months. The cost of preserving the stalks for a longer period would probably be so great under present conditions as to preclude the possibility of the remunerative manufacture of alcohol therefrom. In consideration, however, of the tremendous extent of this source of supply, it seems advisable that those in charge of the agricultural experiment stations and

other experimental investigators throughout the country should study the possibilities of manufacturing industrial alcohol at remunerative rates, at least during a part of the year, from these waste products of the maize crop.

MOLASSES.

The utilization of the waste materials from the sugar factories and sugar refineries for the purpose of making alcohol is a well-established industry. The use of these sources of supply depends, of course, upon the cost of the molasses. When the sugar has been exhausted as fully as possible from the molasses the latter consists of a saccharin product, containing considerable quantities of unfermentable carbohydrate matter, large quantities of mineral salts, and water. In molasses of this kind there is probably not more than 50 pounds of fermentable matter to 100 pounds of the product. Assuming that a gallon of such molasses weighs 11 pounds, it is seen that it contains $5\frac{1}{2}$ pounds of fermentable matter, yielding $2\frac{1}{4}$ pounds of industrial alcohol of 95 per cent strength. It requires about 3 gallons of such molasses to make 1 gallon of industrial alcohol. The quantity of molasses made in the United States as a residual product from the sugar manufacture is difficult to determine. For each ton (2,240 pounds) of sugar produced we may assume that there are $62\frac{1}{2}$ gallons of molasses. Placing the total output of sugar in the United States at 400,000 tons, beet and cane combined, would give a yield of molasses of 25,000,000 gallons.

The quantity of molasses produced in Cuba is three or four times as great as that produced in the United States, thus affording a very extensive source of production of industrial alcohol should it prove profitable to make it from this material. The above data show that when the price of molasses delivered to the refineries falls as low as 5 or 6 cents a gallon it may be considered a profitable source of alcohol.

In 1905, 13,500,000 gallons of alcohol were produced in France from beet-root molasses. The production from this source is decreasing—in 1901 almost double the above amount was made.

WOOD PULP AND SAWDUST.

Many attempts have been made to produce alcohol for industrial purposes from sawdust, wood pulp, or waste wood material. The principle of the process rests upon the fact that the woody substance is composed of cellulose and kindred matters which, under the action of dilute acid (preferably sulphuric or sulphurous) and heat, with or without pressure, undergo hydrolysis and are changed into sugars. A large part of the sugar which is formed is nonfermentable, con-

sisting of a substance known as xylose. Another part of the sugar produced is dextrose, made from the true cellulose which the wood contains.

The yield of alcohol in many of the experiments which have been made has not been very satisfactory. It is claimed, however, by some authors that paying quantities of alcohol are secured. In Simmonsen's process for the manufacture of alcohol one-half per cent sulphuric acid is employed and from four to five parts of the liquid heated with one part of the finely comminuted wood for a quarter of an hour under a pressure of nine atmospheres. It is claimed by Simmonsen that he obtained a yield of 6 quarts of alcohol from 110 pounds of air-dried shavings. Another process which has been tried in this and other countries for converting comminuted wood into alcohol is known as Classen's. The comminuted wood is heated for fifteen minutes in a closed apparatus at a temperature of from 248° to 293° F. in the presence of sulphurous acid (fumes of burning sulphur) instead of sulphuric acid. It is claimed by the inventor that he has made as much as 12 quarts of alcohol from 110 pounds of the air-dried shavings. There is reason to doubt the possibility of securing such high yields in actual practice as are claimed in the above processes. That alcohol can be made from sawdust and wood shavings is undoubtedly true, but whether or not it can be made profitably must be determined by actual manufacturing operations.

WASTE PRODUCTS OF CANNERRIES, ETC.

There are a great many waste products in the fruit industry, as well as in the canning industry, which contain sugar and starch, and it has been proposed to use these for the manufacture of alcohol. It is true that all waste products which contain sugar or starch may be used for alcohol-making purposes, but it is doubtful if many of them will be found of a character which will permit their use in competition with other materials containing larger quantities of fermentable matter. The principal waste materials which may be considered in this connection are the refuse of wine making, fruit evaporating, and canning industries, especially the waste of factories devoted to the canning of tomatoes and Indian corn. In addition to this, the waste fruit products themselves, which are not utilized at all, as, for instance, the imperfect and rotten apples, tomatoes, grapes, etc., may be favorably considered. The quantity of waste products varies greatly in different materials.

The quantities of waste material in grapes and apples, as shown by Lazenby, are as follows: About 25 per cent of the total weight in grapes, with the exception of the wild grape, where it is about 60 per

cent; with apples the average percentage of waste was found to be 23.8 per cent from twenty-five varieties. This included the waste in the core, skin, and the defective apples caused by insects, fungi, bruises, etc. In general it may be said that in the preparation of fruits for preserving purposes about 25 per cent of their weight is waste, and this, it is evident, could be utilized for the manufacture of alcohol. If apples be taken as a type of fruits, we may assume that the waste portions contain 10 per cent of fermentable matters, which, however, is perhaps rather a high estimate. Five per cent of this might be recovered as industrial alcohol. Thus, each 100 pounds of fruit waste in the most favorable circumstances might be expected to

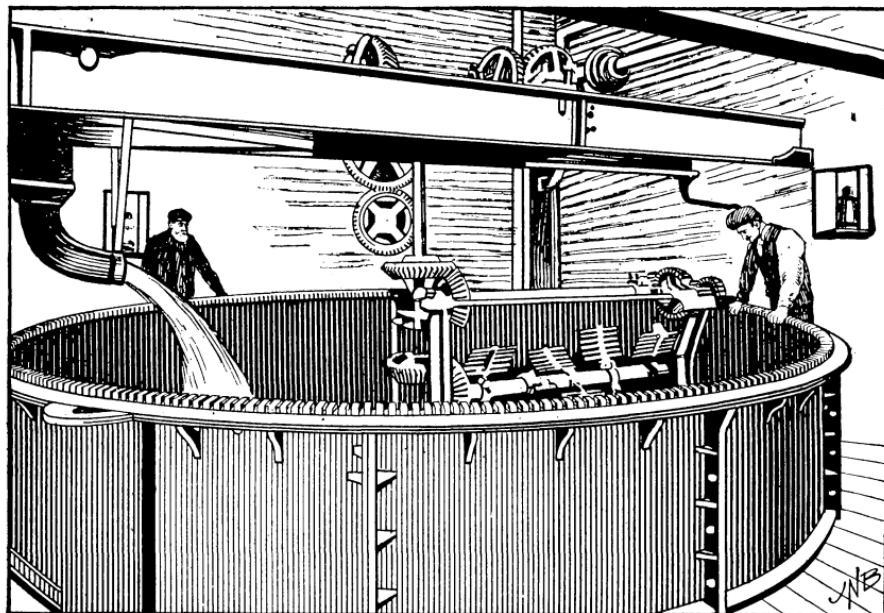


FIG. 3.—Mash tun in an Irish distillery.

produce 5 pounds of industrial alcohol. The quantity of waste which could be utilized for this purpose would hardly render it profitable to engage in the manufacture. A smaller percentage could be expected from the waste of the tomato, where the quantity of sugar is not so great. In the waste of the sweet-corn factory the amount of fermentable matter would depend largely on the care with which the grain was removed. There is usually a considerable quantity of starchy material left on the cobs, and this, with the natural sugars which the grown cobs contain, might yield quite large quantities of fermentable matter. It would not be profitable to erect distilleries simply for the utilization of waste of this kind, but if these wastes could be utilized in distilleries already established it might be profitable to devote them to this purpose.

MANUFACTURE OF ALCOHOL.

The three principal steps in the manufacture of alcohol are (1) the preparation of the mash or wort, (2) the fermentation of the mash or wort drawn off from the mash tun, and (3) the distillation of the dilute alcohol formed in the beer or wash from the fermentation tanks. The preparation of the mash includes (1) the treatment of the material used with hot water to form a paste of the starch or the sugar, and (2) the action of the malt or ferment on the paste to convert the starch into fermentable sugar.

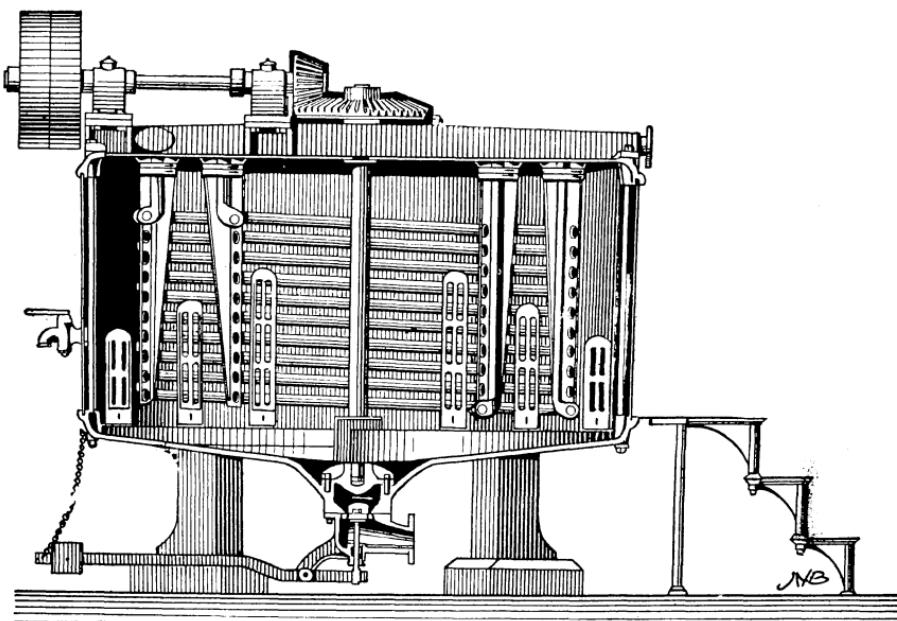


FIG. 4.—Mashing and cooling apparatus, cross section.

MASHING.

Figs. 3 and 4 show two views of the mashing tun or tank, the first figure giving the general appearance, and the second a view of the interior of the tun, showing the machinery by which the stirring is effected and the series of pipes for cooling the finished product down to the proper temperature for the application of the malt.

The object of the mash tun is to reduce the starch in the ground grain to a pasty, gummy mass, in order that the ferment of the malt may act upon it vigorously and convert it into sugar. If the mashing be done before the addition of the malt the temperature may be raised to that of boiling water. If, however, the malt be added before the mashing begins, the temperature should not rise much, if any, above 140° F., since the fermenting power is retarded and disturbed at

higher temperatures. The mashing is simply a mechanical process by means of which the starch is reduced to a form of paste and the temperature maintained at that point which is best suited to the conversion of the starch into sugar.

FERMENTATION.

Fermenting tanks.—The mash, after the starch has all been converted into sugar, goes into fermenting tanks, which in Scotland are called "wash backs," when the yeast is added. A view of the typical wash back is shown in fig. 5. They often have a stirring apparatus, as indicated in the figure, whereby the contents can be thoroughly mixed

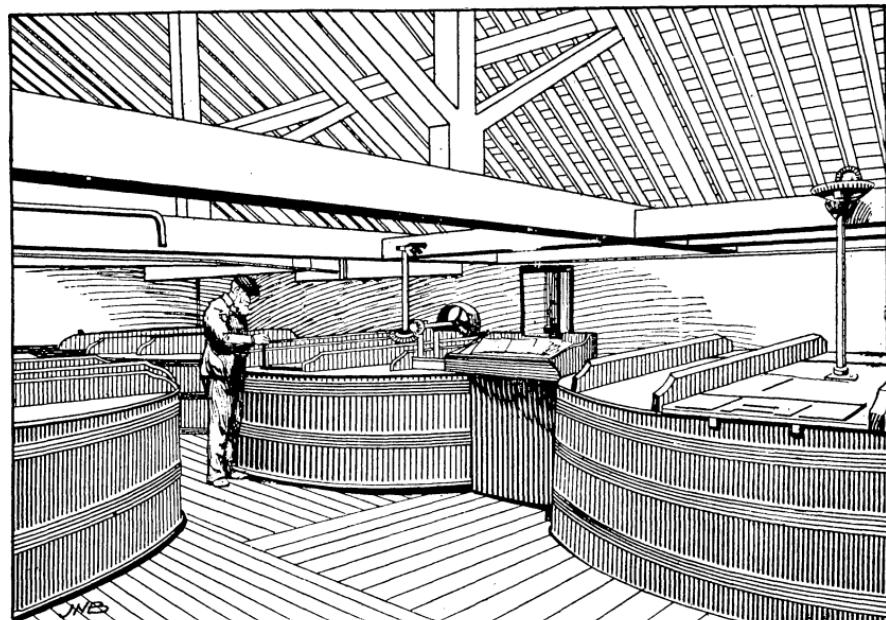


FIG. 5.—Fermentation tanks in an Irish distillery.

with the yeast and kept in motion. This is not necessary after the fermentation is once well established, but it is advisable, especially in the early stages, to keep the yeast well distributed throughout the mass. In these tanks the fermentations are conducted, the temperature being varied according to the nature of the product to be made. For industrial alcohol the sole purpose should be to secure the largest possible percentage of alcohol without reference to its palatable properties.

Action of yeast.—It is unnecessary to go into detailed discussion of the process of fermentation, meaning by that the ordinary alcoholic fermentation. An organism belonging to the vegetable family and to which the name "yeast" has been given is the active agent

in fermentation. The organism itself does not take a direct part in the process, but it secretes another ferment of an unorganized character known as an "enzym" or a "diastase." This enzym has the property, under proper conditions of food, temperature, and dilution, of acting upon sugar and converting it into alcohol and carbonic acid. Anyone who has ever seen a fermenting vat in full operation and noticed the violent boiling or ebullition of the liquor, can understand how rapidly the gas "carbon dioxid" or "carbonic acid," as it is usually called, may be formed, as it is the escape of this gas which gives the appearance to the tank of being in a violent state of ebullition. The yeast which produces the fermentation belongs to the same general family as the ordinary yeast which is used in the leavening of bread. The leavening of bread under the action of yeast is due to the conversion of the sugar in the dough into alcohol and carbon dioxid or carbonic acid. The gas thus formed becomes entangled in the particles of the gluten, and these expanding cause the whole mass to swell or "rise," as it is commonly expressed. Starch can not be directly fermented, but must be first converted into sugar, either by the action of a chemical like an acid, or a ferment or enzym, known as diastase, which is one of the abundant constituents of malt, especially of barley malt. In the preparation of a cereal, for instance, for fermentation, it is properly softened and ground, and then usually heated with water to the boiling point or above in order that the starch may be diffused throughout the water. After cooling it is treated with barley malt, the diastase of which acts vigorously upon the starch, converting it into a form of sugar, namely, maltose, which lends itself readily to the activities of the yeast fermentation. (See figs. 6-8.)

When ordinary sugar (cane sugar, beet sugar, and sucrose) is subjected to fermentation it is necessary that the yeast, which also exerts an activity similar to that of malt, should first convert the cane sugar into invert sugar (equal mixtures of dextrose and levulose)^a before the alcoholic fermentation is set up. The cane sugar is also easily inverted by heating with an acid.

Temperature and materials.—When different kinds of sugars and starches are fermented for the purpose of making a beverage it is important that the temperature of fermentation be carefully controlled, since the character of the product depends largely upon the temperature at which the fermentation takes place. On the contrary, when industrial alcohol is made the sole object is to get as large a yield as possible, and for this reason that temperature should be employed which produces the most alcohol and the least by-products, irrespective of the flavor or character of the product made.

^a See page 13 for explanation of term "invert sugar."

Also, in the making of alcoholic beverages, it is important that the malt be of the very best quality in order that the resulting product may have the proper flavor. In the production of alcohol for industrial purposes this is of no consequence, and the sole purpose here should be to produce the largest possible yield. For this reason there is no objection to the use of acids for converting the starch, cane sugar, and cellulose into fermentable sugars. Therefore, the heating of the raw materials under pressure with dilute acids in order to procure the largest quantity of sugar is a perfectly legiti-

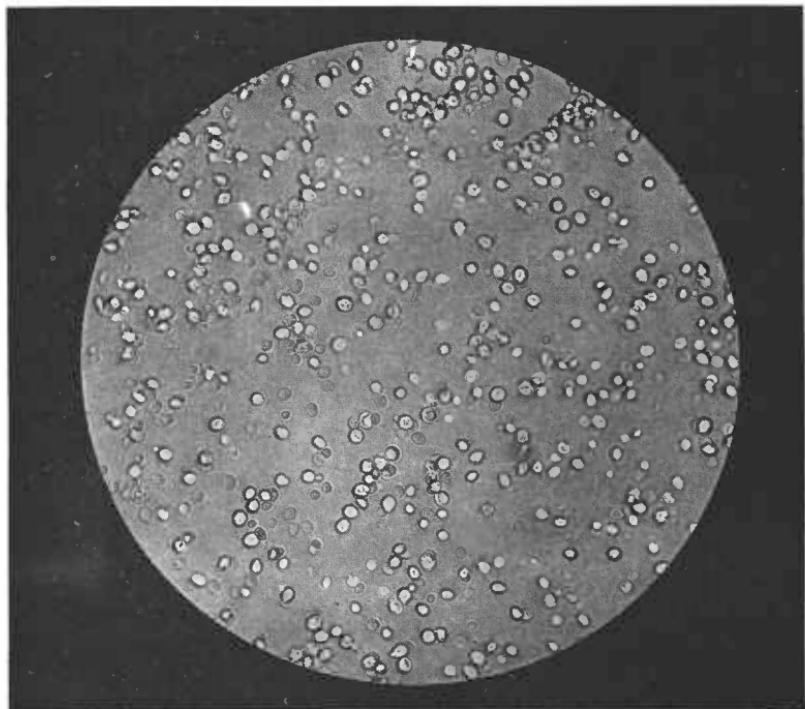


FIG. 6.—Photomicrograph of brewer's yeast ($\times 250$).

mate method of procedure in the manufacture of industrial alcohols.

Sugars and starches are usually associated in nature with another variety of carbohydrates known as cellulose, and this cellulose itself, when acted upon by an acid, is converted very largely into sugars, which, on fermentation, yield alcohol. For industrial purposes, the alcohol produced in this manner is just as valuable as that made from sugar and starch. Whether the diastatic method of converting the starch and sugar into fermentable sugars be used, or the acid method, is simply a question of economy and yield. Whichever method gives the largest quantity of alcohol at the smallest expense

is certain to come into general use. On the other hand, when alcoholic beverages are to be made, those processes must be employed, irrespective of the magnitude of the yield, which give the finest and best flavors to the products.

DISTILLATION.

The object of distillation is to separate the alcohol which has been formed from the nonvolatile substances with which it is mixed. A typical form of distilling apparatus for the concentration of the dilute

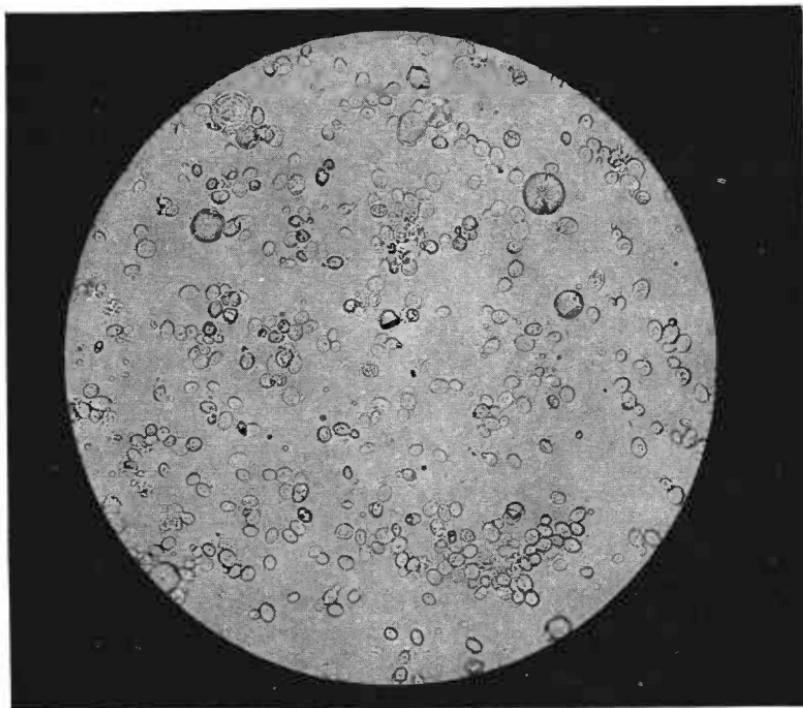


FIG. 7.—Photomicrograph of household yeast; large grains are starch ($\times 250$).

alcohol, which is formed in the beer or wash from the fermentation tanks, is represented in fig. 9.

This apparatus is of the continuous type common to Europe and America. It consists of a "beer still" provided with a number of chambers fitted with perforated plates and suitable overflow pipes. It is operated as follows:

The sirup and alcohol are pumped into the top of the beer still through a pipe *G*; the tank *G* may also be placed above the center of the still and the contents allowed to flow into the still by gravity; steam is admitted through an open pipe into the kettle *A* at the bottom of the column or is produced by heating the spent liquor by means of a coil. The steam ascends through the perforations in the plates, becoming richer and richer in alcohol as it passes through

each layer of liquor, while the latter gradually descends by means of the overflow pipes to the bottom of the column *B* and finally reaches the kettle completely exhausted of alcohol, whence it is removed by means of a pump connected with the pipe line *H*. On reaching the top of the beer still *B* the vapors of the alcohol and the steam continue to rise and pass into the alcohol column *C*. This column is also divided into chambers, but by solid instead of perforated plates, as shown at *K*. Each chamber is provided with a return or overflow pipe and an opening through which the vapors ascend. In the alcohol column the vapors are so directed as to pass through a layer of liquid more or less rich in alcohol which is retained by the plate separating the compartments. An excess of liquids in these compartments overflows through the down pipes, gradually works its way into the beer still, and thence to the kettle. On reaching the top of the column the vapors, which have now become quite rich in alcohol,

are passed into a coil provided with an outlet at the lowest part of each bend. These outlets lead into the return pipe *P*, which connects with the top chamber of the alcohol column. This coil is technically termed the "goose" and is immersed in a tank called the "goose tub." A suitable arrangement is provided for controlling the temperature of the water in the tub by means of outlet and inlet water pipes. When the still is in operation the temperature of the "goose" is regulated according to the required density of the alcohol. The object of

FIG. 8.—Yeast from beer sediment showing budding ($\times 1270$).

the "goose" is the return to the column of all low products which condense at a temperature below the boiling point of ethyl alcohol of the desired strength. On leaving the "goose" the vapors enter a condenser *E*, whence the liquid alcohol is conducted into a separator *F*. This separator consists simply of a glass box provided with a cylinder through which a current of alcohol is constantly flowing. An alcohol spindle is inserted in this cylinder and shows the density of the spirit at all times. A pipe, with a funnel-shaped opening at its upper extremity, connects with the pipe leading from the condenser and gives vent to any objectionable fumes. The separator is connected by means of a pipe with the alcohol storage tank. The pipe *O* is for emptying the upper chambers when necessary. The valves *N*, communicating by means of a small pipe with a condenser *M*, are for testing the vapors in the lower chambers for alcohol.

Another form of distilling apparatus operated on much the same principle as the one just described is shown in fig. 10.^a

CONCLUSIONS.

From the preceding discussion the farmer will be readily able to determine the actual value of the raw products he produces for alcohol-manufacturing purposes. The manufacture of alcohol on a very small scale is not likely to prove profitable. Experience has shown that attempts to manufacture sugar and other substances of a similar character on a small scale can not compete with similar manufacturing industries on a large scale, and the regulation requiring that the

^a For detailed description of this apparatus see Brannt, Distillation and Rectification, p. 214.

alcohol be 180 proof, as before mentioned, will make it difficult, if not impracticable, in the majority of cases for the farmer to produce industrial alcohol on a small scale. A co-operative distillery might, however, be profitably conducted in farming communities.

The still must be constructed as prescribed by law and the process conducted in all its details according to the regulations of the internal revenue, with such exceptions as are noted in the revised regulations of July 15, 1907.^a It is evident that in most cases the farmer must be content with producing the raw materials and that he can not look forward to becoming a practical distiller. The distilling interests, on the other hand, will have an industry quite distinct and apart from the agricultural interests producing the raw materials.

^a U. S. Internal Revenue, Regulations and Instructions concerning the Tax on Distilled Spirits, etc., No. 7, Revised April 15, 1901; Regulations No. 30, Revised; U. S. Internal Revenue, Regulations and Instructions Concerning Denatured Alcohol, under the act of Congress of June 7, 1906, and amending act of March 2, 1907. July 15, 1907.

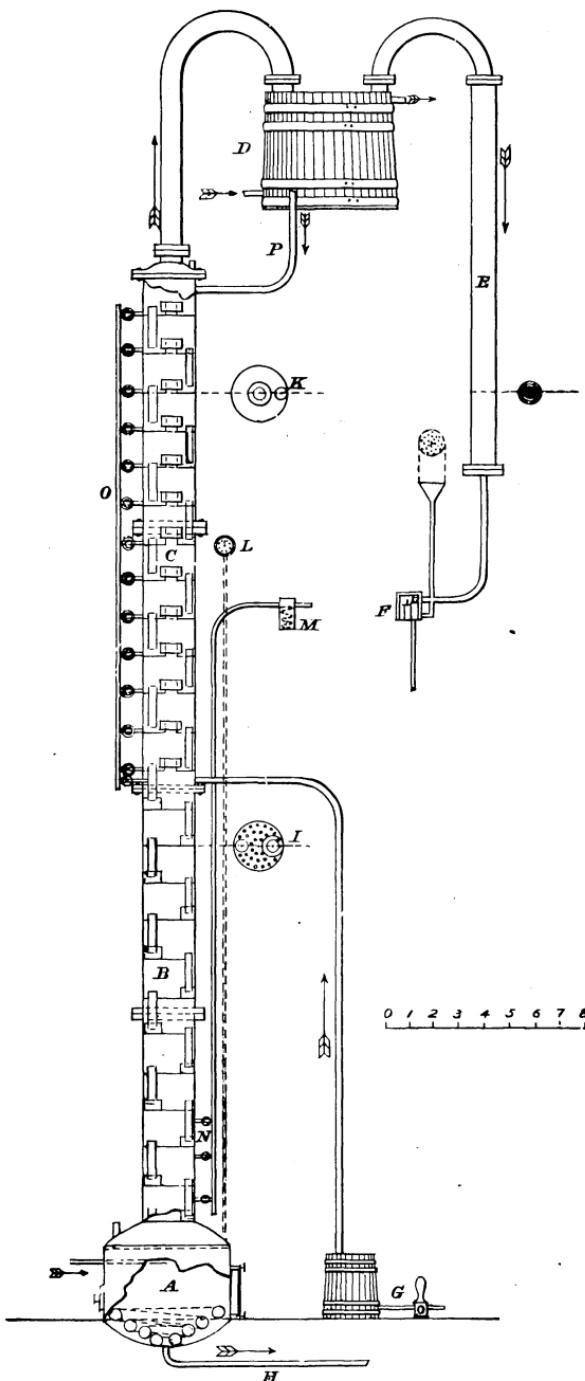


FIG. 9.—Continuous distilling apparatus.

The principal uses of industrial alcohol are illumination, heating, motive power, and the manufacture of lacquers, varnishes, smokeless powder, medicinal and pharmaceutical preparations, vinegar, ether, etc. Our farmers are chiefly interested in these matters as they refer to illumination, heating, and motive power. When industrial alcohol is made at a price at which it can compete with petroleum and gasoline, it will doubtless be preferred for the purposes above mentioned because of its greater safety and more pleasant odor.

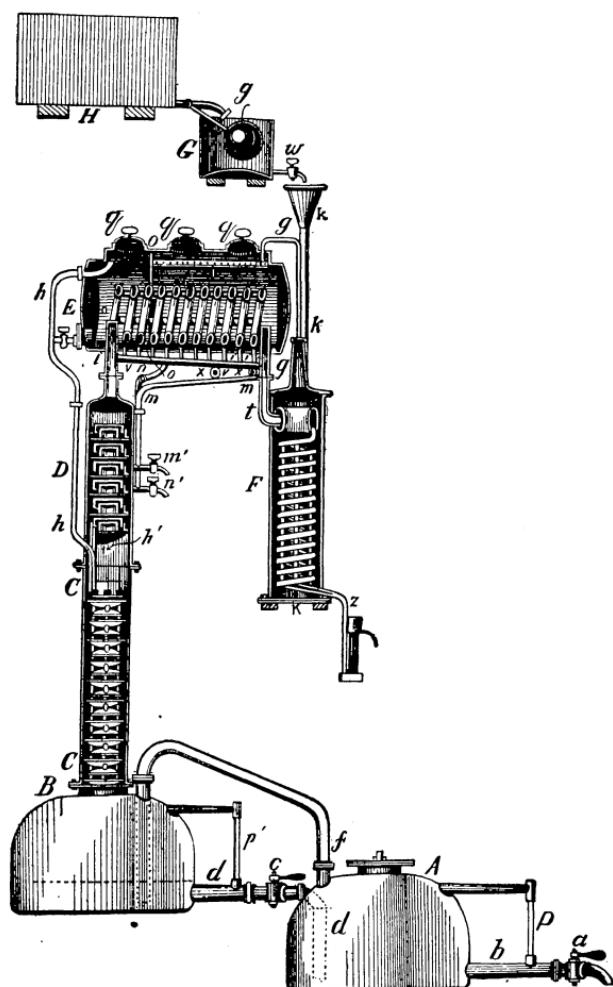


FIG. 10.—Another form of continuous still for making alcohol.

Under the present conditions it is not probable that industrial alcohol can be offered upon the market at much less than 40 cents per gallon of 95 per cent strength. It is believed, however, that by paying attention to unused sources of raw materials and increased production thereof, with improved methods of manufacture and denaturing,

the price can be very much diminished. As the price falls the quantities used for industrial purposes will correspondingly increase, so that small profits both to the farmer and to the manufacturer will bring large returns by reason of the greater quantities of the materials handled.

The benefits which are to accrue from the use of industrial alcohol free of tax have probably been overestimated by the people at large, and especially by the farmers, but that material benefits will accrue is not a subject of doubt. These benefits will come, not suddenly, but slowly, as agricultural products are more abundant, technical methods of manufacture improved, and the methods of utilizing the industrial alcohol better understood. Our people should not, however, be disappointed should many years elapse before the magnitude of the product used for industrial purposes reaches the figure already attained by Germany and some of the other European nations.

Of the raw materials which can be utilized for the manufacture of alcohol, Indian corn is by far the most abundant and the most promising source at the present time. The average price of potatoes must be very much decreased before raw material of this kind can come into competition with Indian corn as a source of alcohol. Promising sources which are not now utilized for the manufacture of alcohol in this country are the potato, the sweet potato, the yam, sorghum, molasses from the cane-sugar and beet-sugar factories, and the Indian-corn stalk. Waste materials of other manufacturing industries, such as those related to fruits and vegetables, may incidentally be utilized for manufacturing purposes, but could not of themselves become independent sources of profitable industrial alcohol.

